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ABSTRACT

Research on the emergence of sex differences in spatial ability during early adolescence prompted a meta-analysis of 172 spatial ability studies conducted since 1974. The meta-analysis confirmed that there are actually several spatial abilities, that some types of spatial ability show marked sex differences while others show none, and that spatial constructs manifesting sex differences show them as early as the construct has been measured. Studies in the meta-analysis were divided according to three spatial constructs: mental rotation, spatial perception, and spatial organization. Significant sex differences, in favor of males, were found in mental rotation and spatial perception. A longitudinal study of 335 young adolescents revealed strong sex effects (males higher) and grade effects (8>7>6) on the Primary Mental Abilities Test. Another study of 135 high school seniors revealed a timing of puberty effect showing better spatial ability among late maturers on the Embedded Figures Test. Some sex differences in test strategy were found. It was also found that adolescents, especially boys, who participated in spatial activities did better on spatial tasks. These analyses suggest that sex differences in mental rotation skill emerge before adolescence and are little affected by adolescent development and socialization. It is possible that both biological and social factors could account for the observed sex differences. (NRB)

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August, 1985

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Factors Influencing Sex Differences in Spatial Ability During Adolescence

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Presentation in a symposium "Sex Differences in Mental Rotation Ability Across the Lifespan" at the annual meeting of the American Psychological Association in Los Angeles, California, August, 1985.

In their major review of the research on sex differences, Maccoby and Jacklin (1974) concluded that the sex difference in spatial ability emerged during early adolescence. This inference has led to a decade of research examining both biological and social explanations for this timing of emergence. Biological hypotheses have focused primarily on the timing of pubertal maturation while social hypotheses have focused on sex role development as well as sex-related experiences, particularly course taking and spatial activities. This research has produced a number of interesting findings, only a few of which will be discussed in this brief presentation.

The recent research on the emergence of sex differences in spatial ability during early adolescence also stimulated Marcia Linn and I (1985, in press; 1986, in press) to conduct a meta-analysis of 172 spatial ability studies since 1974. The meta-analysis confirmed what each of us were finding in our separate studies. First, there is not a single spatial ability but rather several spatial abilities. Second, some types of spatial ability, including mental rotation, show very marked sex differences while others show none. Third, those spatial constructs manifesting sex differences show them as early as the construct has been measured. I will elaborate the relevant findings of the meta-analysis just a bit before summarizing findings from my own research.

In our meta-analysis we found heterogeneous effects leading us to divide the studies according to three spatial constructs: mental rotation, spatial perception (of horizontality or verticality), and

spatial organization--the latter accounting for the largest number of studies and tests. Only with the first two constructs did we find significant sex effects, both in favor of males. The mental rotation effect size was not homogeneous, with differences for the two types of tests used (Figure 1). The Shepard-Metzler/Vandenberg three-dimensional mental rotation test (Figure 2) showed a sex effect of one standard deviation while the effect size on Primary Mental Abilities (PMA) Space subtest and other two-dimensional tests was only one-third of a standard deviation. The fact that the three-dimensional task is too difficult for prepubertal children, of course, confounds the developmental issue. Sex differences on two-dimensional mental rotations tests, however, are found as early as the tests have been used; 10 years of age was the youngest in our meta-analysis.

For example, in my longitudinal study of 335 young adolescents (Petersen, 1984, describes this study more fully), we found strong sex effects (males higher) and grade effects (8>7>6) on the PMA test (Figure 3). The meta-analysis results would lead us to expect no effect of pubertal timing or status for either boys or girls; indeed, we have found none (Petersen, 1983; Petersen & Crockett, in preparation). The social hypothesis that participation in activities involving complex spatial fields would be related to spatial performance was partly supported (Figure 4), however, in that boys who were rated as skilled in field sports requiring spatial ability scored highest on the PMA test (Richards, 1980). We cannot unconfound cause from effect in this finding but we hypothesize that experiences requiring complex mental rotations will develop this cognitive skill.

In a second study of 135 post-pubertal adolescents (high school seniors), we found a timing of puberty effect showing better spatial ability among late maturers (Figure 5)--as was found initially by Waber (1975, 1976, 1977)--but for only one spatial test: the Embedded Figures Test (Figure 6). This test showed no sex difference in our study or in the meta-analysis. Conversely, there was no timing of maturation effect with the Vandenberg Mental Rotations test although we found the expectable, large sex difference (Petersen, 1981; Petersen & Gitelson, in preparation).

In this study, we also attempted to discover whether there were test-taking strategies that accounted for the sex difference. The first thing we learned was that it is difficult to identify what strategy is used with a non-verbal task. Indeed, boys--but not girls--who gave us extended verbal reports were usually poor visualizers. We did code as spatial non-verbal responses such as arm waving to indicate manipulations; that strategy response, however, did not differentiate the performance of boys and girls. The strategy that produced the best mental rotations performance for boys, and was related to the biggest sex difference in performance although it was reported by exactly the same number of boys and girls, involved rotating the figure around a fixed point (Petersen & Gitelson, in preparation). To examine speed of performance, we looked at the number of items left blank at the end of the test; these are plotted by spatial performance on the next slide (Figure 7). We found a striking interaction such that girls classified as average or high in spatial visualization on the Guilford-Zimmerman Clock test left the most blank while average and high boys on this test left the fewest blank.

We found that the associations between participation in spatial activities and spatial performance were similar for boys and girls though only moderate in magnitude (.31 for boys and .27 for girls). There was little variation in the magnitude of correlations across tests for boys (ranging from .26 to .38) but larger variation for girls (.12 to .37). The largest correlations were with the two tests not showing significant sex differences: the Embedded Figures Test and the DAT Space Relations subtest; this suggests that the spatial activities identified may not be ones important to mental rotations skill. No systematic significant relationships were found between spatial ability and sex role orientation.

In conclusion, sex differences in mental rotation skill emerge earlier than adolescence and are little affected by adolescent development and socialization. There are some sex differences in test strategy but we are not sure how to interpret our findings. Similarly, we find that adolescents--especially boys--who participate in spatial activities do better on spatial tasks, including mental rotations. We cannot, however, unconfound cause and effect.

We still believe, however, that both biological and social factors are likely to account for the observed sex differences. Although there clearly is great within-sex variation, existing data cannot rule out the possibility of a very small group difference or predisposition early in life; such a small (and significant) initial predisposition could become amplified by the relatively greater involvement of boys in experiences that develop mental rotation skill. Such experience could operate directly on skill development and less directly on brain development.

(See Petersen and Hood, in press, for a more extended discussion of this hypothesis.)

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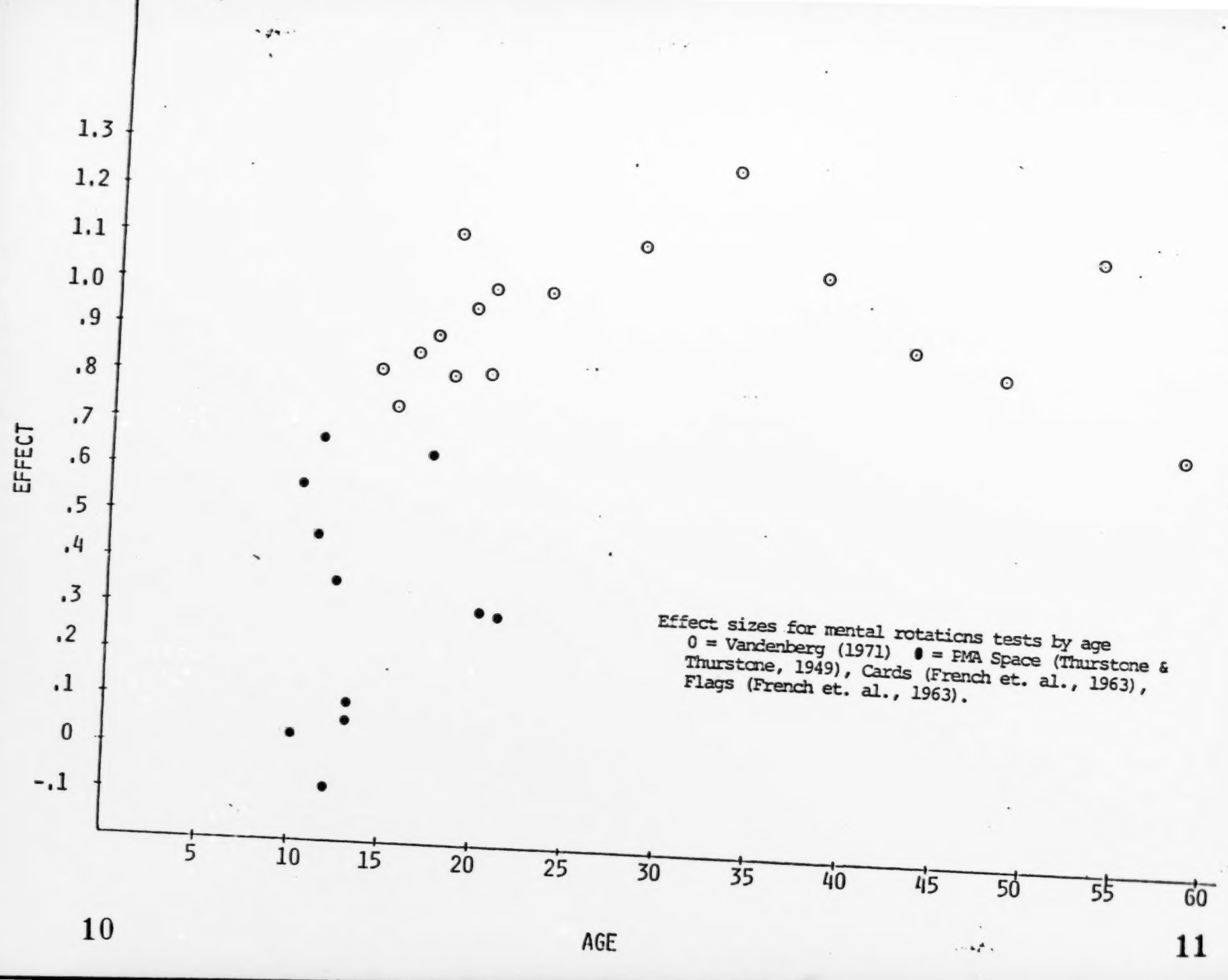
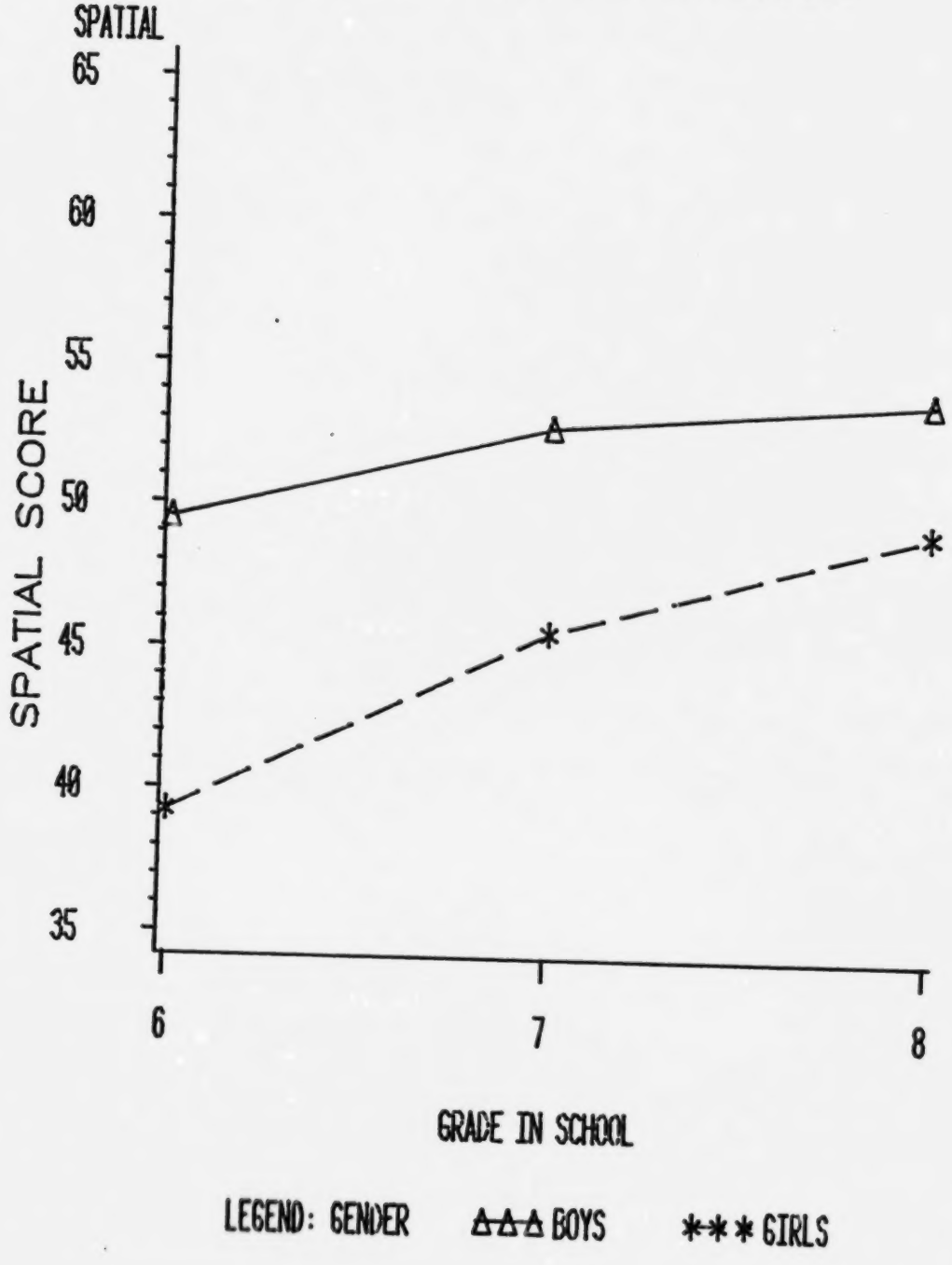
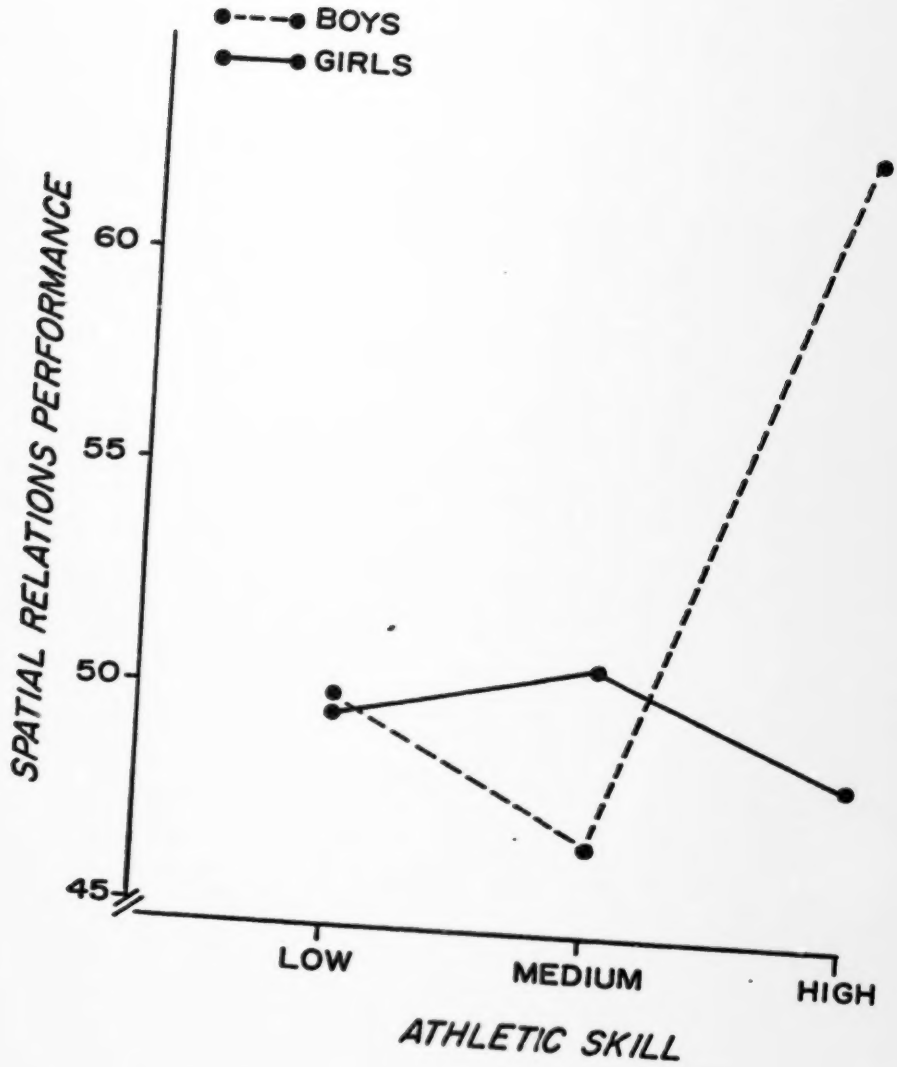
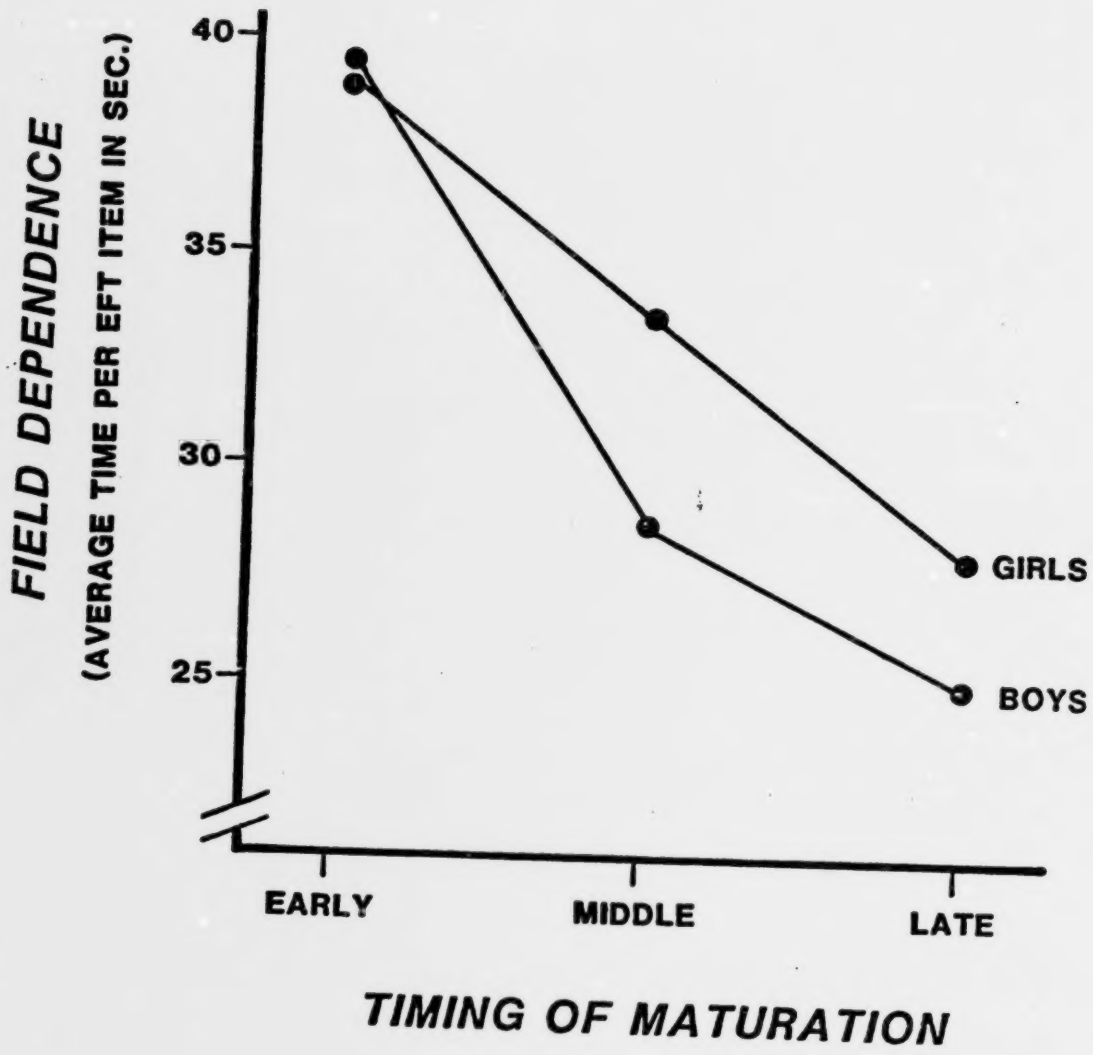


Effect sizes for mental rotations tests by age
0 = Vandenberg (1971) ● = PMA Space (Thurstone & Thurstone, 1949), Cards (French et. al., 1963), Flags (French et. al., 1963).

CHANGES IN SPATIAL ABILITY OVER EARLY ADOLESCENCE



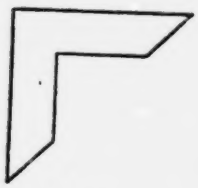

BOYS
GIRLS
SPATIAL RELATIONS PERFORMANCE
60
55
50
45
LOW
MEDIUM
HIGH
ATHLETIC SKILL

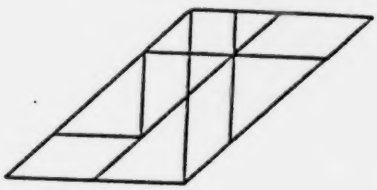

FIELD DEPENDENCE
(AVERAGE TIME PER EFT ITEM IN SEC.)
40
35
30
25
GIRLS
BOYS
EARLY
MIDDLE
LATE
TIMING OF MATURATION

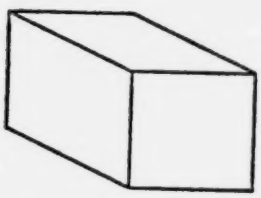
SPATIAL VISUALIZATION:

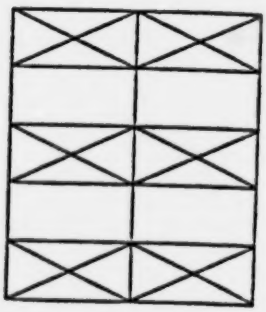
EMBEDDED FIGURES TEST

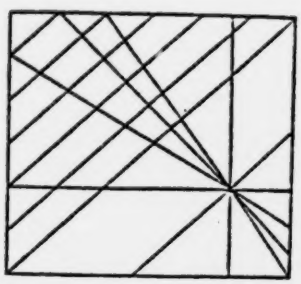
FIND THE SIMPLE SHAPE (ON LEFT) IN THE COMPLEX SHAPE (ON RIGHT).







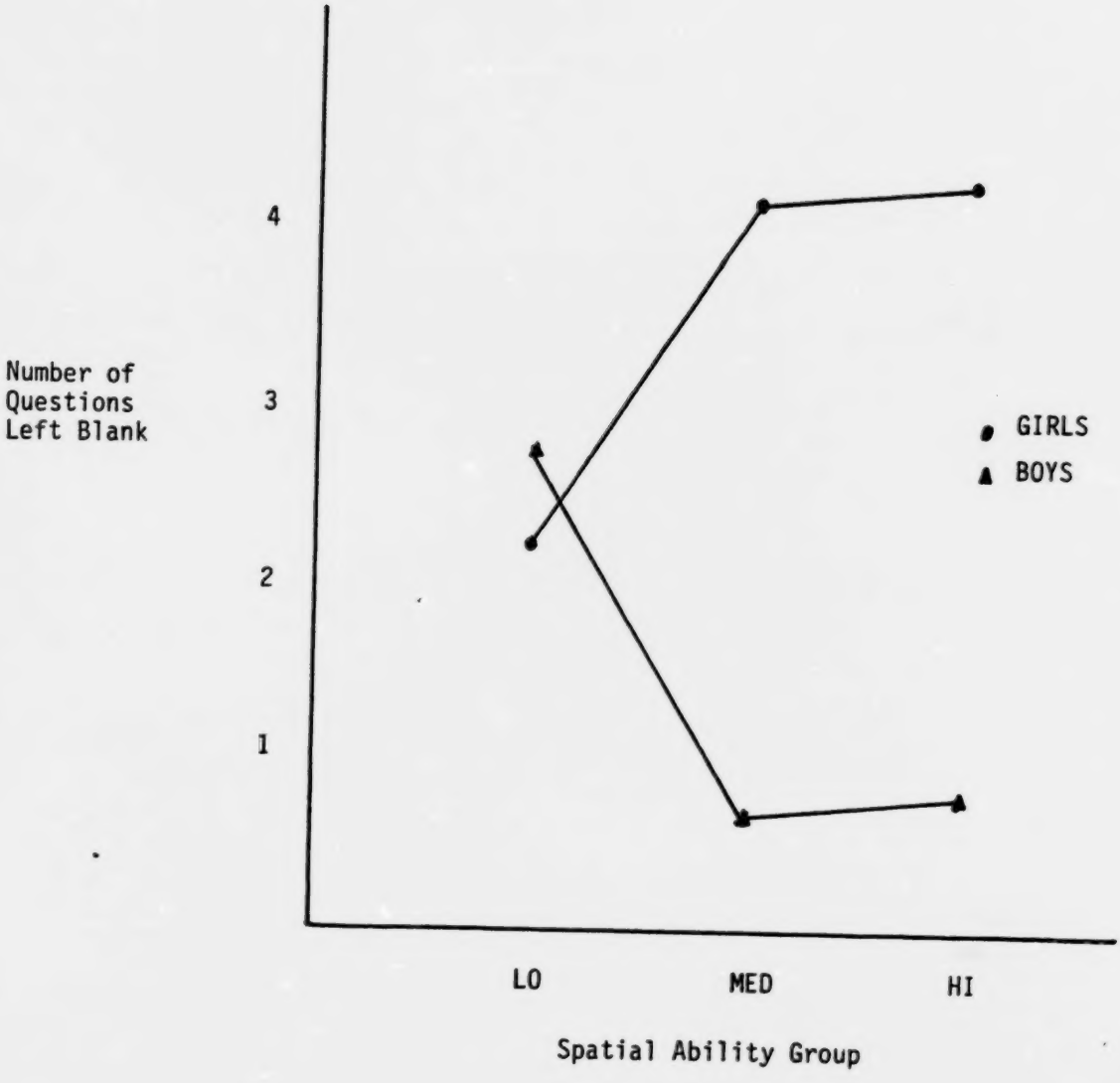




Sex and Spatial Ability Effects

on Test-Taking Style

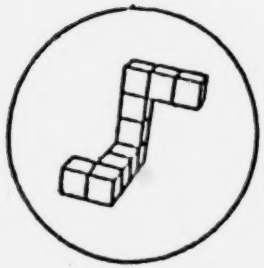
(# Left Blank at End of Test)



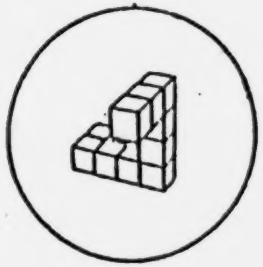
MENTAL ROTATION TEST

WHICH OF THE RESPONSES SHOW A DIFFERENT VIEW OF THE STANDARD? (TWO ARE CORRECT)

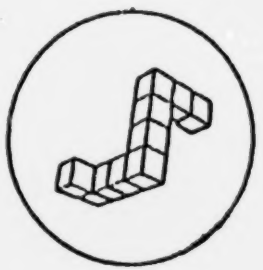
STANDARD



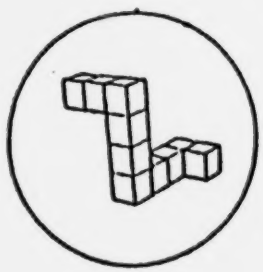
RESPONSES



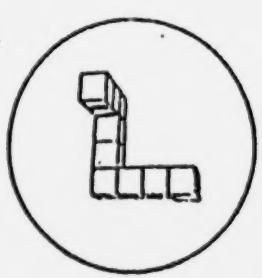
1



2



3



4